filled with calcite or other amygdaloid minerals, thin beds of tuffaceous or scoriaceous debris lying upon the lava surface or between the fragments of top crust, and fragments of chilled crust that have cracked off and become engulfed in the upper part of the flow.

The complex relations between the two facies prevented mapping of individual flows or of main bodies of lava in such units as would be useful as horizon markers. These relations assist, however, in determining the direction of lava movement and if studied over a larger area would eventually lead to more exact knowledge of centers of eruption. The matters of most immediate interest to mining are the different reactions of the massive and fluidal facies of lava to fissuring and the resultant effects upon the width and structure of the veins. (See pp. 208-210.)

Another feature of the latite flow member is the occurrence of thin lenses and locally of great thicknesses of breccia and tuff between the flows. Between smaller spurts and offshoots of the main flows there are breccia beds that have accumulated in favorable places, producing alterations of flows and breccias, but these breccias are not usually of great thickness. On Round Mountain and adjacent ridges of Whale and Silver Lake Basins 600 to 700 feet of breccia occurs in such relations as to indicate its accumulation during eruption of the flows, but evidently from an independent source or at least by entirely different phases of the volcanic eruptions. The beds have a regional dip on Round Mountain of 15° to 20° to the east or northeast. As shown on the geologic map, a lower tongue of lava is interbedded with breccia in the basal part, but the higher flows and greater proportion of them lie upon slopes of the breccia. This breccia cannot be separated by its general appearance from the lower tuff-breccia of the Burns, but an arbitrary division was chosen at a horizon of conglomerate and sandy tuff at about the base of the flows. For convenience, the breccia will be hereafter referred to simply as the breccia of Round Mountain. Completion of studies in Whale Basin and on Kendall Peak may give further data for subdivision of the Burns latite, but for the preliminary map the separation of the breccia body of Round Mountain from both the flows and lower breccia is desirable, as it forms the country rock of several productive veins of the Silver Lake system.

The upper tuff member of the Burns latite is described in the Silverton folio as especially prominent near the head of the Animas River and farther east, where fossiliferous beds of limestone and shale furnishing evidence of the age of the Silverton series were found. Near Arrastre Basin these upper tuffs and limestones are exposed on the high cliffs of Little Giant Mountain and on the ridges extending east and south. The base of the upper tuff as chosen for mapping is at a limestone or calcareous tuff bed about 1 foot thick. There is about 100 feet of tuff belonging to the Burns latite above this horizon, and this is overlain in turn by the pyroxene andesite flow that caps Little Giant Mountain and part of King Solomon Mountain.

Relation of Productive Lodes to Burns Latite

By far the greatest production near the Arrastre Basin has come from different rocks of the Burns latite. This is probably due in part to its intermediate position in the volcanic sequence and its predominance in the area, and in part to the fact that its tuffs and breccias have physical properties favorable to simple fissuring. The lower tuff-breccia member is the country rock in part of the present Shenandoah-Dives mine, at the lower levels of the Silver Lake and New York veins, and in several other mines. The latite flow member is the country rock in the old workings beneath the North Star and Dives claims, and along parts of the Iowa and Royal Tiger veins. The breccia of Round Mountain forms the wall rock at higher levels of the Silver Lake, New York, Royal, Stelzner, and other veins of this system. (See Pl. V, C and D.) Judged by records of earlier mining as well as by its observed reaction to fissuring, the massive facies of the latite flows is less favorable than the interbedded breccias or the fluidal facies, both of which are softer rocks. Ransome[8] reports concerning the North Star mine, "The hard massive sheets of andesite [mas-

[8]Ransome, F. L., op. cit., (Bull. 182) p. 164.

sive facies of the Burns flows] are found to be less favorable for the deposition of ore than the softer breccias." This difference is probably to be accounted for by a splintery fracture and the complex systems of fissuring consequently produced in the massive facies. These physical properties cause the formation of a lode or compound vein occupying a series of parallel fault fissures united by diagonal fissures. The opening of these diagonal fissures is controlled in many places near Arrastre Basin by differential movements of fault walls. Diagonal fissures in hard massive rocks may be filled with large veins under favorable conditions, but where the lode consists of a series of partly overlapping and narrow ore streaks diagonal to the main trend of the fissure system it is difficult to mine efficiently. In the breccias and softer fluidal facies these diagonal fissures are much less pronounced and form a smaller angle with the trend of the main fissure system. The productive lode is thus composed of ore streaks more nearly parallel to the mine drifts, and is therefore more efficiently mined by single wide stopes. The theory of the origin of these fissure systems and its application to the different rocks and to mining problems are discussed more completely on pages 195-212.

Pyroxene Andesite

The pyroxene andesite is the uppermost formation of the Silverton volcanic series in this area and covers much of the surface in the central part of the Silverton quadrangle, north of the Animas River. The top part of Little Giant Mountain and the ridge extending east from it are composed of a massive basal flow of pyroxene andesite above an altitude of 13,-100 feet. The southern part of the King Solomon Mountain ridge is composed of this same flow but is only partly shown on plate I. The andesite flow of these ridges is a dark-colored massive lava not greatly differing in general appearance from the massive facies of the Burns latite. It does differ, however, in a greater abundance of pyroxene, less conspicuous feldspar crystals, and a more granular texture of the dark-colored base, and compares closely with basal flows of pyroxene andesite north of the Animas River. The rock is unimportant as a wall rock of the vein systems under discussion but serves the useful purpose of providing a check on fault displacements. It is probable that the massive lavas of this formation of the Silverton series compare closely with the massive facies of the Burns flows in their reaction to fissuring and effect upon vein systems.

INTRUSIVE ROCKS

Andesite and latite dikes

Two groups of dikes that perhaps represent six or seven intrusions are found within Arrastre Basin. They are of andesitic or latitic composition and differ in texture and in the proportions of feldspar, hornblende, biotite, and augite. The dikes of one group strikes about N. 80° E. and those of the other between N. 45° W. and N. 70° W. The northwesterly dikes include the Mayflower dike of the Shenandoah-Dives fissure, the dike of the Silver Lake fissure, the Magnolia dike east of Silver Lake, and two dikes appearing in the extension of the Titusville fissure at the Buckeye mine.

The Mayflower dike has been followed by the underground development to a position vertically beneath Little Giant Mountain, but on the surface it is lost in the vein outcrop about 2,500 feet northwest of the peak, where it possibly passes into the footwall of the fissure and fails to break through the massive latite flows that form the surface rock. The dike is a porphyritic andesite of dominantly feldspathic composition and is locally amygdaloidal. The amygdules of calcite are commonly elongated parallel with the dike walls and its direction of emplacement, which is generally steep, The dike ranges in width from 10 or 15 feet to nearly 40 feet where exposed in underground workings.

Without much doubt the Silver Lake and Magnolia dikes represent the same intrusion but occur in overlapping fissures separated about 2,000 feet at their outcrops. The Silver Lake dike has been followed along the vein outcrop for a distance of about 2,500 feet but turns eastward from the vein on the cliffs northwest of Silver Lake, ending in a sickle-shaped curve a few hundred feet in the hanging wall of the vein. It has not been followed northwest of the area shown on plate I but is believed to continue beyond the gap above the old Nevada mine. The dike dips 50°-65° N.E., parallel with the local dip of the vein fissure, and has a width of 10 to 20 feet. It is greenish gray, contains crystals of hornblende and feldspar, and shows a somewhat denser fluidal texture at the edges. The Magnolia dike, which is of the same composition and texture, is exposed prominently in a curving course down the east slope of Round Mountain, then assumes a fairly uniform southeasterly course to the ridge east of Silver Lake, where it curves eastward, and after crossing the ridge its extension is concealed beneath the talus of Dives Basin. The two fissures occupied by these dikes are complementary breaks of the same origin and perhaps connect beneath the surface. Along its northwesterly course the Magnolia dike dips 55°-65° N.E., like the Silver Lake dike, and has a width of 10 to 15 feet.

At the outcrop of the Buckeye vein two andesitic dikes occupy the fissure, which has a strike of N. 65°-70° W., and are evidently the result of a compound intrusion. About 300 feet southeast of the old mine buildings a branch of one dike goes into the northeast wall of the main fissure. These two dikes are believed to continue northwestward beyond the gap just east of the Titusville mine, as shown on plate I.

The N. 80° E. group includes two prominent parallel dikes exposed in Arrastre and Whale Basins, that on the north extending through the Arabian Boy claim and that on the south under the north end of Silver Lake. These dikes will be called for convenience the Arabian Boy dike and the Arrastre dike. The Arabian Boy dike is feldspathic and somewhat porphyritic and closely resembles in places some latitic flows of the Burns. It also contains hornblende and is locally amygdaloidal. It has been traced from the ridge of Kendall Peak to the east end of Dives Basin, a distance of 12,000 feet, but it extends farther in both directions. The dip of the dike where it crosses the ridges on either side of Arrastre Basin is 75°-85° N. It attains a width of 30 to 35 feet but narrows eastward to 10 feet or less. It does not differ greatly in general appearance from the Mayflower dike, but there is no clear evidence that the two were intruded simultaneously. The deep workings of the Shenandoah-Dives mine beneath Little Giant Mountain apparently had not reached the crossing of the Mayflower and Arabian Boy dikes in the fall of 1932.

The Arrastre dike is likewise a feldspathic andesite and has been traced from the ridge of Kendall Peak 7,500 feet east to the head of Dives Basin. Near the head of the basin it is only a few feet in width and shows evidence of splitting into small branches. No trace of its extension was found beyond the talus-covered area, so that it is probable that the dike ends near the head of Dives Basin. Its westward extension beyond the ridge of Kendall Peak is not known.

There are discontinuous exposures of greenish-gray latitic or andesitic dikes at places near the trail from Cunningham Gulch into Dives Basin. They strike N. 60°-70° E., and may be the eastward fingering out of deeper portions of either the Arrastre or the Magnolia dike.

Until the entire Kendall Peak area south of Silverton has been mapped, the relation of these dikes to the large monzonitic intrusions near Silverton (pl. III) must remain in doubt, but there is some reason to suppose that these dikes are later than any volcanic formations in this region and were probably intruded during the initial fracturing of the lavas. They may be related in origin to the earliest phases of the latest intrusive activity. Some support to this suggestion is afforded by the lines of flowage of the prominent east-west dikes, which pitch 60° or more to the west and indicate a movement of the magma from beneath the outcrops of the main monzonitic masses near Silverton. The presence of these dikes and the steep pitch of the flow lines is also evidence of the great continuity in depth of the fissures in which they occur.

Monzonitic porphyries

In addition to the above-mentioned dikes, small intrusive bodies of monzonitic rocks occur close by but not within the area shown on plate I. They are shown on plate III, which represents a part of the Silverton quadrangle mapped by

Cross and Ransome, with some additions by the writer. The nearest body is in Cunningham Gulch and cuts diagonally across from Stony Gulch to the northeast slope of King Solomon Mountain. It has a length of about 1½ miles and a width of a quarter of a mile. It ranges in composition from aplitic granite to monzonite porphyry, but porphyry greatly predominates.[9] To the north of this body a larger dikelike mass crosses the mouth of Cunningham Gulch just above Howardsville and extends northeastward across Maggie Gulch, with a total length of about 3 miles and a maximum width in Maggie Gulch of about half a mile. The rock of this body resembles the quartz monzonite of Sultan Mountain in its granular texture.

All these porphyritic monzonite rocks are believed to be associated with the igneous activity that attended the intrusion of the Sultan and Bear Mountain quartz monzonite stock described in the Silverton folio.[10] This large body has a length, east and west, of about 5 miles and a width of 2 miles. It is granular in texture and of medium-fine grain. With it are associated darker facies of fine-grained rocks that have a higher content of augite, hornblende, and biotite, and also lighter facies of granitic and aplitic composition.

This stock visibly crosscuts about 4,000 feet of formations that range from pre-Cambrian basement in Animas Canyon to the San Juan tuff on the crest of Sultan Mountain, and also intrudes into the Silverton volcanic rocks of Anvil Mountain north of Silverton. The contact metamorphism of sedimentary beds and volcanic formations adjacent to the stock is intense and is expressed by marbleization of limestones, formation of garnet, pyroxene, epidote, and probably, in impure limestones, by vesuvianite. The surrounding rocks are impregnated with specular hematite for some distance from the stock.

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[9] Cross, Whitman, and Howe, Ernest, op. cit. (folio 120), p. 12.
[10] Idem, pp. 11, 12.

Geologic Structure

Prevolcanic Structure

The structure of the pre-Cambrian and Paleozoic formations need be considered only briefly, as it probably had little if any local influence on the structure of vein systems in the overlying volcanic rocks. There is a possibility that basement structure has influenced the more regional pattern of late Tertiary deformation, but this feature cannot be considered until more is known both regionally and locally about structural details of the pre-Cambrian and Tertiary rocks. Arrastre Basin is situated near the inner margin of a late Cretaceous and early Tertiary uplift of the ancestral San Juan Mountains, which produced the westward and southward dips of the Paleozoic sedimentary rocks in the Animas Valley below Silverton. A number of troughlike fault blocks inside the margin of uplift complicate the regional structure in Cunningham Gulch and elsewhere. Beneath the center of Arrastre Basin, however, erosion preceding and following deposition of the Telluride conglomerate cut so deep into the Archean schists that there is little chance that explorations at the base of the volcanic series will find large down-faulted blocks of sedimentary beds.

General Structure in the Volcanic Rocks of Animas Valley

As the Arrastre Basin map fails to picture the general geologic setting of the region about Silverton, the smaller-scale map is presented as plate III. It is based mainly on the map in the Silverton folio, to which further detail and the results of some reconnaissance mapping have been added. These additions show to the extent permitted by present knowledge the general character of the Animas Valley fault system.

The structural features of the region may be divided into four groups. The first includes the structural relations of different volcanic formations to one another and complex details of structure in individual volcanic units within the formations, which have been partly described in preceding pages. The second group comprises the Animas Valley fault system, and the third includes structural features of the andesite, latite, and porphyry dikes and the larger intrusive masses of quartz monzonite. The fourth group may be defined as including all the latest fissures and faults that controlled the location of ore bodies in the region and are believed to have been the secondary effects of major faulting along the Animas Valley. This last group includes structural details discovered during actual mining of ore bodies. It is by far the most complex and difficult to analyze, yet the most important to the operator concerned chiefly with efficient development and removal of ore from ground known to be mineralized. New exploration and development, on the contrary, are much concerned with the regional distribution of ore bodies, and the general features controlling such localization will be described first.

Animas fault system

The Animas fault system is the major structural feature of the region and is known, partly from actual tracing and partly by inference, to extend from the east side of the quartz monzonite stock near Silverton beyond Eureka toward the head of the Animas Valley. The faults of this system have a bow-shaped trend convex to the southeast. They turn gradually from a N. 60° E. strike near Silverton to N. 15° E. and north-south near Eureka. The zone of faulting ranges from 1 to 2 miles in width and consists of a series of nearly parallel and branching fault planes, some of which are well exposed along the lower part of Arrastre Creek. One fault plane with an estimated throw of 700 to 800 feet is exposed on the east side of the gulch about 1,200 feet north of Cascade Creek. It has a strike of N. 65° E. and dips steeply northward. The Eureka rhyolite and Burns latite are strongly altered in the vicinity of the fault and sheeted parallel to its direction. The fault zone, only a few feet in width, is composed of sheared rock and a rubble of abraded fragments cemented by gouge. This fault plane is evidently only one of several such planes within a distance of 400 or 500 feet, because to the north the base of the Burns flows is down-faulted below the talus bordering Arrastre Creek. Most of these faults are largely concealed by talus and soil, but where the soil covering is thin their direction is plainly marked by a zone of altered rock. Several other faults are well exposed in the Burns latite outcrops on the slopes facing the Animas Valley and in the bed of the Animas River, but displacements on individual faults cannot be determined at these places. The total displacement measured from the top of the Burns breccia on the northeast side of Arrastre Creek to its position in the bed of the Animas River amounts to a little over 2,300 feet. (See section, pl. III.) The displacement as measured from the base of the pyroxene andesite on the top of Little Giant Mountain to its base north of the Animas Valley amounts to a little over 2,400 feet. The width of the fault zone at this place is about 5,000 feet, and although by no means all the fault planes have been recognized or mapped, it is probable that the major displacement took place on three or four larger faults such as the one described. Between Galena Mountain and the Animas Valley the displacement appears to be about the same, but individual faults have not been traced and are indicated only diagrammatically on plate III. From the southeast side of the monzonite intrusion in Maggie Gulch to the northwest side of the Animas Valley the displacement amounts to about 1,900 feet, and at Eureka, where two of the fault planes were shown on the map in the Silverton folio, the displacement has decreased to about 1,000 or 1,500 feet.

The character of movement on the faults of the Animas Valley system is known only locally, but some of the faults of Arrastre Gulch show slickensides that are alined essentially down the dip of the fault plane. If this movement can be taken as characteristic of the zone as a whole, these major faults differ from the minor fissures and faults extending southeastward into Arrastre Basin, which have a comparatively large horizontal component of displacement (pl. I).

The greater movement on the faults of the Animas system must have been of premineral age, as all major faults and the fissures paralleling them show alteration of the walls similar to but more intense than that of walls adjoining the nearby veins. Quartz, sericite, pyrite, epidote, chlorite, and specularite in different proportions constitute the principal alteration products along the faults. Some movement of post-mineral age or occurring late in the epoch of mineralization is indicated by the displacement of veins by the faults and by mineralized material that has been sheared and abraded by friction within the faults.

Intrusive Rocks

The relation of the larger intrusive bodies of quartz monzonite to the Animas fault system has already been briefly mentioned and can readily be seen from plate III. The large faults apparently do not offset or displace these intrusive bodies, and therefore the greater part of the faulting seems to have occurred before or during the injection of the quartz monzonite magma. This inference is confirmed, moreover, by the elongate shape of the intrusive body between Howardsville and Maggie Gulch, indicating the control of the fault system on the direction and shape of this body.

In addition to these major intrusive masses along the fault zone, there are in and near Arrastre Basin smaller andesitic, latitic, and granitic dikes striking both parallel and radially to the fault zone. Some of these dikes are shown on the detailed map of the basin, but in addition there are several dikes farther south, shown on the map in the Silverton folio. The dikes of Arrastre Basin were intruded into fissures along which there was comparatively little faulting prior to their injection, and they perhaps represent the filling of tension cracks produced during early stages of intrusive activity. Some of these dikes are of considerable economic importance, as the fissures in which they occur were the sites of later fissuring, faulting, and mineralization. Other dike-bearing fissures, although but weakly mineralized themselves, were probably feeder channels that extended from depths close to sources of the mineralizing solutions to shallower fractures in which larger ore bodies were localized.

Regional Structure and Mineralization

Subsidence and marginal faulting

The bow-shaped fault zone of the Animas Valley region has been shown to form the southeast margin of a great down-faulted block, and by considering this faulting in relation to regional structure in the Silverton quadrangle it appears that this sunken block includes a large mass of roughly triangular outline, which extends from Mineral Creek on the west to the Animas Valley and northwestward and northward to the Red Mountain district and the vicinity of Treasure Mountain. This sunken mass or volcanic sink has a width from the Animas fault to Red Mountain of about 8 miles, and a length from the Bear Mountain stock to Treasure Mountain of about 10 miles (plate III). The marginal faults of this volcanic sink are described below, and the probable relation of structure to igneous activity and mineralization in the Silverton and Telluride quadrangles is discussed on pages 164-174.

The displacement of the Animas faults near Eureka amounts to about 1,000 or 1,500 feet, and their strike has turned to N. 15° E. Near Eureka Mountain the displacement on the north-south fault that crosses the mouth of Eureka Gulch is taken up by a prominent series of northeasterly faults that form a zone about 2 miles in width. The general effect of this system is to fault down a wedge-shaped block that narrows northeastward between the Cinnamon and Rainbow faults to a width of less than a mile. The structure of this fault zone farther east, in the Lake City quadrangle, is complicated by relatively high masses of pre-Cambrian granite, but this structure is evidently foreign to the sunken block of the Silverton quadrangle and has merely complicated local faulting where the two structures adjoin. This sunken wedge of the Treasure Mountain area therefore forms a northeasterly projection of the main sunken block, and is bounded on the northwest by the great Cinnamon fault and its southwest extension that pass into the fault and fissure systems of the Sunnyside mine, at the head of Eureka Gulch. Cross and Howe[11] have presented evidence to show that the northwestward striking Ross Basin fault is part of this fault system and takes up the greater part of the throw of the Sunnyside system. The Ross Basin fault drops the pyroxene andesite downward to the south at least 1,000 feet, as the base of the ande-

[11]Cross, Whitman, and Howe, Ernest, op. cit. (folio 120) p. 23.

site is faulted below the level of Eureka Gulch and Cement Creek. It is not improbable, however, that the throw may exceed this figure considerably. If the base of the andesite maintains the uniform level shown in the surrounding country the displacement would be nearer 1,500 to 2,000 feet. The Ross Basin fault has been traced to the head of Gray Copper Gulch with apparently undiminished throw, but westward toward Red Mountain the extreme alteration of the volcanic rocks made recognition of different formations so difficult that in the Silverton folio they were not differentiated and the fault line was not indicated. There can be little doubt, however, that the fault extends westward to the Red Mountain Valley, where the displacement is taken up by a series of northeasterly faults.

The faults systems of Cement Creek and the Red Mountain Valley describe a bow-shaped curve like those of the Animas Valley but are convex to the west and limit the entire western margin of the sunken block. The most striking evidence of the intensity and nature of faulting along this zone is shown by large blocks of the Potosi volcanic series (flows of latitic and rhyolitic composition succeeding the Silverton volcanic series) which have been down-faulted below the level of Mineral Creek above Chattanooga. The Silver Ledge mine[12] is situated on the eastern fault bounding the sunken rhyolite bodies, and as the 400-foot level of this mine is in Potosi rhyolite it is evident from the normal position of the rhyolite on adjoining ridges that the displacement of this block must have exceeded 2,300 feet. This displacement does not, however, represent the net effect of the fault zone but merely the adjustment of fault blocks within the marginal zone. The net displacement must be somewhat less than the displacement of the rhyolite block, as otherwise rhyolite instead of pyroxene andesite would be exposed east of the fault; but changes in thickness of the different volcanic formations and uncertainty as to how deep the rhyolite extends below the level of the mine workings make the extent of this displacement likewise indeterminate.

[12]Ransome, F. L., Economic geology of the Silverton quadrangle: U. S. Geol. Survey Bull. 182, pp. 247, 248, 1901.

An approximation of the net displacement south of this position along Mineral Creek may be obtained from the fact that the San Juan tuff is not exposed on the east side of the valley but on the west side extends 800 to 1,500 feet above the valley floor. As the lavas on the east side are chiefly pyroxene andesites, representing the upper part of the Silverton series, the displacement must exceed 1,500 feet and probably is not less than 2,000 feet. The difficulty of obtaining an exact measurement of displacement along Mineral Creek is due partly to the fact that the Silverton lavas thin markedly toward the west and partly to the fact that intense alteration along the fault zone prevented the mapping of individual members of the series. However, when allowance is made for changes in thickness of the formations, it seems likely that the net displacement ranges from 2,000 to 2,500 feet near the Bear Mountain stock to 1,000 feet or less near the head of Mineral Creek. Cross and Howe[13] have called attention to evidence indicating the northeastward extension of the Mineral Creek fault zone through the Red Mountain zone of ore deposits to the head of Ironton Park. The chimneylike ore bodies of the National Belle, Yankee Girl, Robinson, Guston, and Paymaster mines are all alined along an altered fault zone of north-northeast trend, and about half a mile east of this zone another line of chimney deposits extends through the St. Paul, Congress, Hudson, and Genesee-Vanderbilt mines. The localization of chimney deposits along these fault-lines is believed to have been controlled in part by cross fissures of east-west and northwest trend, such as those that limit the ends of the downthrown blocks of rhyolite. The approximate position where the fault zone would be intersected by a westward projection of the Ross Basin fault is shown by the dotted lines on plate III. Thus the entire margin of the area bounded by the Animas Valley above Silverton, Mineral Creek, the Red Mountain Valley, Ross Basin, and the Treasure Mountain region is marked by steep faults whose displacements indicate relative subsidence of the central block ranging from 1,000 feet or less to about 2,500 feet.

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[13]Cross, Whitman, and Howe, Ernest, op. cit. (folio 120), pp. 23, 24.

Intrusive and extrusive activity

The quartz monzonite intrusive bodies along the Animas fault from the Bear Mountain stock nearly to Eureka have been described above and are shown on plate III. Another line of monzonite or granite porphyry intrusions extends up Mineral Creek toward Red Mountain, and several dikes and two larger stocks of an intrusive rock, termed quartz syenite porphyry by Cross, occur in the Red Mountain district. They are much more alkalic than the normal monzonitic rocks farther south along Mineral Creek. Between Red Mountain and Ross Basin no intrusive rocks occur along the fault zone, or if any are present the bodies are too small to have been shown on the Silverton folio map. Near Treasure mountain are numerous dikes and sheets of intrusive rhyolite of felsitic texture, many of which are displaced by fault systems of this area, but some larger dikelike bodies are alined parallel to the faults, suggesting that these intrusives were partly localized by fissuring but that the major fault displacement took place after intrusion. Except for about 4 miles between Ross Basin and Red Mountain, the border of the down-faulted block is thus characterized by a marginal zone of intrusive bodies.

Outward from the east, south, and west sides of this sunken block there is a marked decrease in thickness of the Silverton series; the most abrupt change in the formations occurs near the edge of the down-faulted block. It is therefore possible that at least these sides of the structure were localized by the distribution of the Silverton series, but as yet no faults of Silverton age have been recognized or differentiated from those of post-Silverton age. In the central part of the Silverton quadrangle there is 3,000 feet of the pyroxene andesite flows, and if we add to this the normal thickness of Burns latite and Eureka rhyolite, nearby, the total thickness of the series here must have reached 4,000 to 5,000 feet, whereas the maximum thickness of the series on the west and south of the area close to the marginal faults rarely exceeds 1,500 to 2,000 feet and decreases rapidly to a few hundred feet not many miles distant. A part of this difference is accounted for by the erosion that followed the Silverton epoch and preceded the eruption of the Potosi series, but the preservation of the series in the down-faulted blocks shows that a broad depression occupied the central part of the Silverton quadrangle and that it was filled with eruptive debris of the Silverton epoch. Though not essential to the structure this evidence suggests that down warping of the area caused by the extra heavy load of volcanic debris may have weakened the crust during the Silverton epoch; but the sunken block as it now exists retains the approximate margins of this earlier basin only along the south and west sides.

Fissuring and mineralization

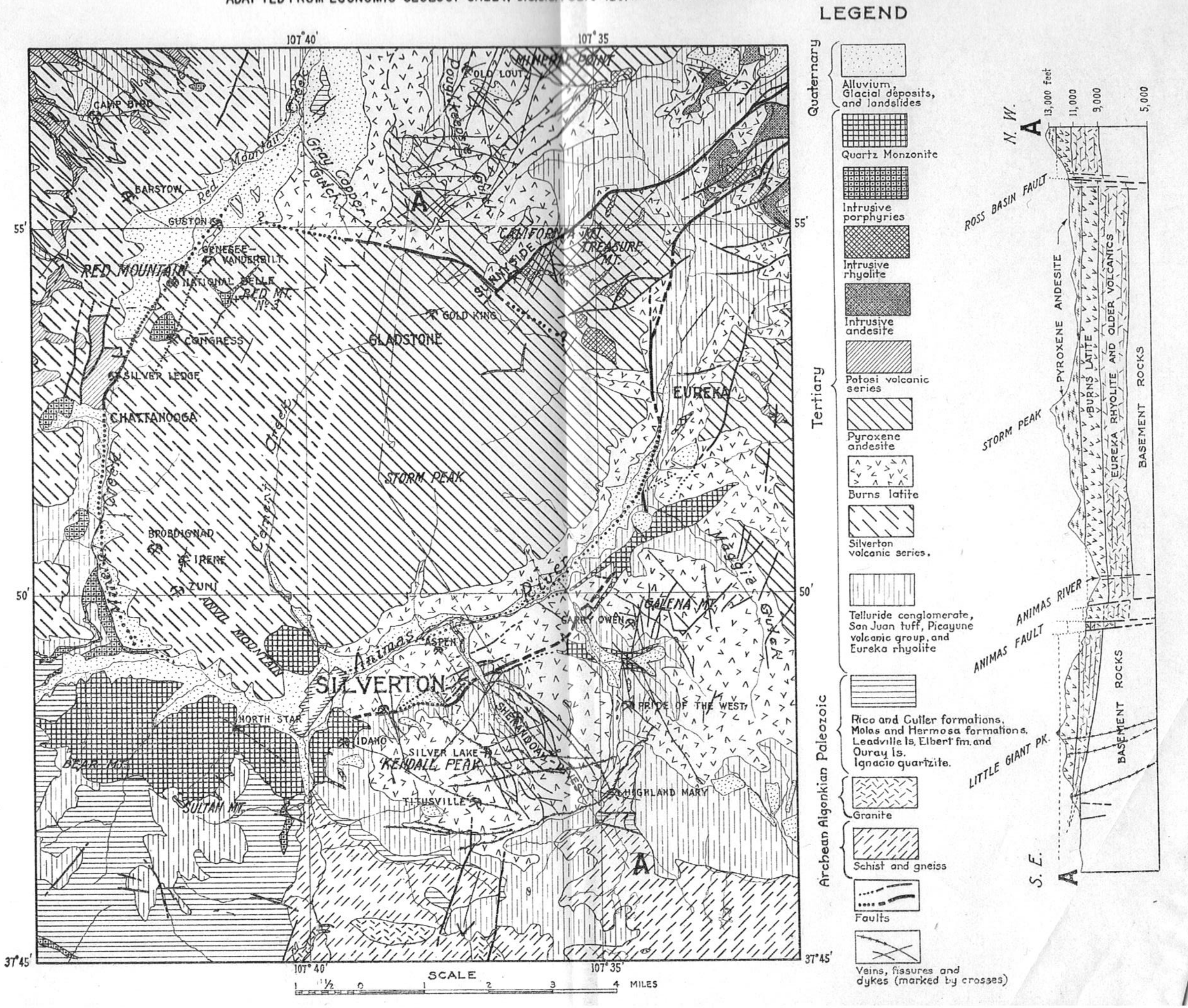
A map (pl. IV) showing important fissure veins in the Silverton quadrangle indicates that most of them do not parallel the marginal faults of the sunken block but are distributed radially, somewhat like the spokes of a wheel about the hub. Many complex factors are involved in the production of this radial fissuring, and our present knowledge of details in different parts of the quadrangle does not permit analysis of these factors for each sector of the region. It is known, however, that the great zone of northeasterly fissuring and faulting in the Treasure Mountain region and the zone of northwesterly fissuring on the mountain ridges west of the Red Mountain Valley are in part related to a regional structural pattern that involves adjoining centers of igneous and dynamic activity. Perhaps when all the facts are known it may be found that the subsiding block of the Silverton quadrangle is but one of many conjunctive elements of the structural pattern in the western San Juan region and that these seemingly independent centers are closely related both in time and origin. The description of the structural features about the sunken block is made without implying that they were all developed by forces originating solely within the Silverton center.

Southern Area

South of the sunken block a marginal zone of fissure veins 3 to 4 miles in width extends from the Bear and Sultan Mountain stock eastward through Galena Mountain to and beyond

GEOLOGY OF A PORTION OF THE SILVERTON QUADRANGLE, COLO.

ADAPTED FROM ECONOMIC GEOLOGY SHEET, U.S.G.S. FOLIO 120, WITH CHANGES AND ADDITIONS BY W.S.BURBANK.



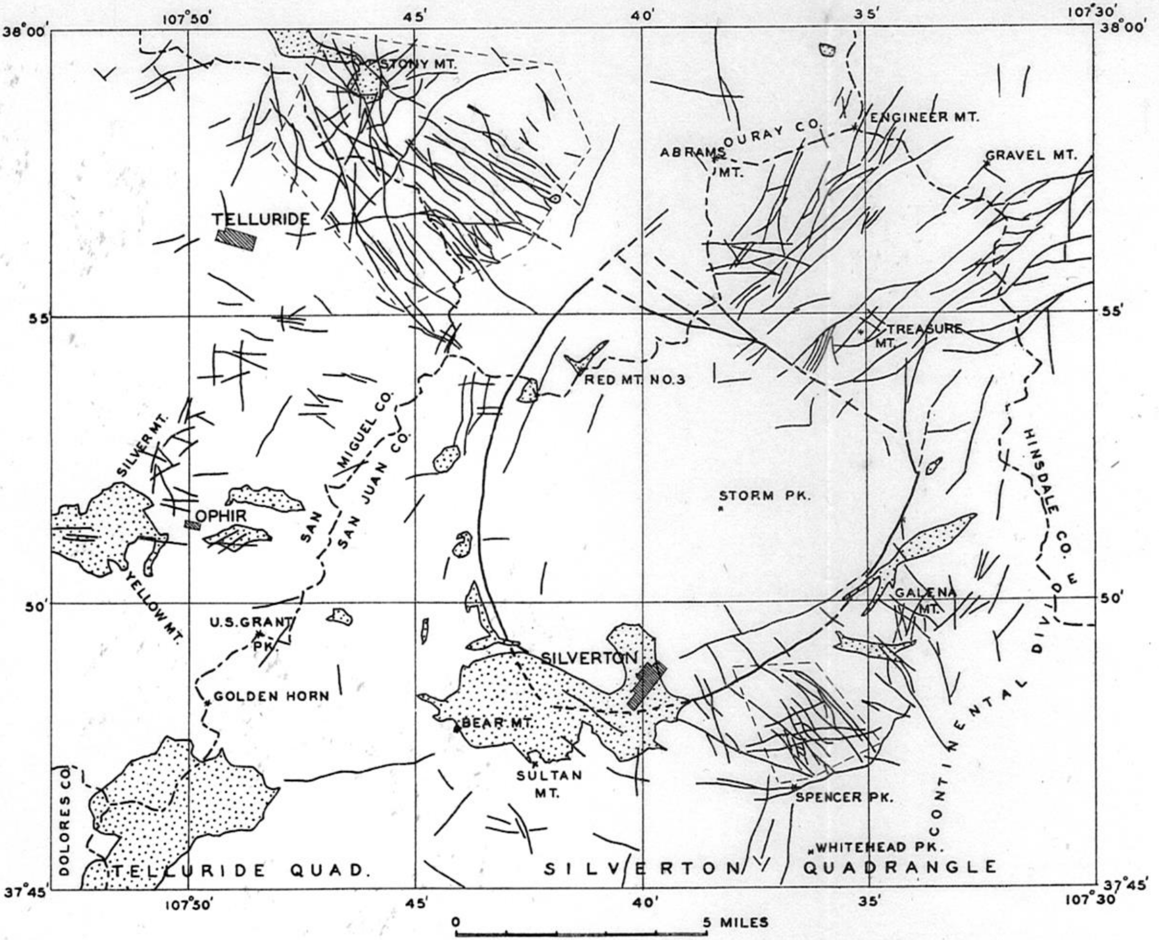


Plate IV. Pattern of the fracture systems and principal cross-cutting intrusive bodies in the Silverton quadrangle and eastern part of the Telluride quadrangle. Two areas which have been mapped on a scale of 1 in.-1,000 feet are outlined by light dashed lines.

Maggie Gulch. Most of these veins strike northwest to north and belong to that group disposed radially about the sunken block, but a lesser number strike east to northeast, more or less parallel or oblique to the marginal faults. The ores are chiefly the base-metal sulphides, from which the most valuable recovered metals have been lead, silver, and gold. There is a rough zonal distribution of the different kinds of ore suggesting that the igneous intrusions and the Animas fault were the principal agents controlling sources and trunk channels by which the mineralizing solutions were fed into the open fissures in which ore bodies were deposited. Ores occurring in the northwesterly fissures immediately adjacent to the Animas fault zone near Arrastre Basin contain some specularite and are characterized chiefly by the base-metal sulphides, chalcopyrite, galena, and sphalerite, with a gangue of quartz and chlorite. Locally they carry sufficient free gold associated with the chalcopyrite to make it an important constituent of the ore. Ore bodies in the same fissures a mile or two farther southeast contain the base metals also, but argentiferous tetrahedrite or freibergite becomes an abundant constituent of the ores and barite, rhodochrocite, and manganiferous calcite become more abundant constituents of the gangue. Gold is here the less important and silver the more important constituent of the ore. Barren quartz and calcite succeed these silver ores still farther southeast from the fault zone. The eastern zone of the mineralized area near Maggie Gulch is characterized by extremely siliceous ores with finely disseminated sulphides and argentite. Pyrite is common in the ores. They were mined for their gold and silver content only. The ores of Sultan Mountain, at the west, contain the base-metal sulphides with some tetrahedrite in a gangue of quartz and barite and in the past were mined chiefly for their silver and lead content. The most heavily mineralized and most massive base-metal veins are those of the Arrastre Basin and Silver Lake mines and the veins of Cunningham Gulch, which lie about in the center of the mineralized province south of the Animas fault. There are, however, sufficient exceptions to an idealized zonal arrangement to indicate that structure has been locally more influential than the commonly accepted temperature zones in controlling distribution of the different ores. Furthermore, it is apparent that the largest exposed body of quartz monzonite west of Silverton does not lie above the source from which ore solutions emanated, but rather that this body and the several smaller bodies are only shallow manifestations of more deeply buried bodies of molten rock that were rising along the marginal faults and that remained partly molten long after the solidification and fracturing of intrusive rocks now exposed. The section on veins of Arrastre Basin (pp. 182 seq.) described some of the mines of this area in more detail.

Northern Areas

On the north and northeast sides of the foundered block there are one or more areas that appear to be independent of the one south and east of Silverton, but with the possible exception of certain local ores the mineralogic characteristics suggest that there was a common magmatic source or at least that the magmas underlying this portion of the crust had certain common characteristics. This border zone includes the veins of the Treasure Mountain area, the Sunnyside group, and those near Poughkeepsie Gulch and Mineral Point. The radially disposed veins of this group strike from N. 20° E. to N. 60° E., and the veins parallel and diagonal to the marginal faults strike from N. 50° W. to west. Here, as in the Animas Valley, the radially disposed fissures form the larger group numerically, but all systems of fissures are mineralized. The most productive veins now are those of California Mountain and Sunnyside Basin, which form part of the fault system limiting the down-faulted block of the Treasure Mountain area. Past production has also been made from many veins of Poughkeepsie Gulch and Mineral Point, of which the Old Lout was the most profitable. The ores of Sunnyside Basin are chiefly the base-metal sulphides, galena, sphalerite, and chalcopyrite, but they are distinguished from the base-metal ores of the Animas Valley by the abundance of associated silicates